Is Now Part of

To learn more about ON Semiconductor, please visit our website at
www.onsemi.com

AN-6105
USB Type-C Design Considerations
USB Type-C Adapters

Summary

USB is a ubiquitous connector that is used by many customers and in many different applications. With the official release of the USB Type-C connector, many companies are racing to implement this new connector and the supporting infrastructure. The early adopters of this connector will be faced with many challenges as different vendor's release products that are either non-compliant or designed to earlier versions of the specification.

One specific challenge is with USB Type-C adapter cables and how they are implemented. The adapter cables are critical for new designs because they allow backward compatibility to the existing USB infrastructure. Vendors are making a wide range of adapter cables which can cause detection issues which need to be considered. This application note describes these considerations and possible solutions to the problems faced.

Analysis

The USB Type-C specification defines a USB Type-C to USB Standard-A cable assembly which requires that the Type-C plug CC pin be connected to VBUS through a resistor Rp (Section 3.5.1, Table 3-12, page 59, note 2). The USB Type-C specification further defines the Rp value to be the Default USB Power value (Section 4.5.3.2.2, page 146, paragraph 1). This Rp pull-up resistor to VBUS in the cable ensures that a Type-C sink port will properly connect to a legacy standard-A source port which always supplies VBUS. The adapter cable does not control what is connected into the standard-A side and what power capabilities it has so the adapter must advertise Default USB Power to ensure that the Type-C sink port does not try to consume more power than the legacy port can provide.

When a Type-C to standard-A adapter cable is connected to a Type-C port that either is a source port, or capable of acting as a source port, and is not connected to the legacy standard-A port, it creates a circuit that can cause issues with the standard Type-C detection shown in Figure 1. Note that a similar circuit can potentially be created with USB Type-C wall chargers that have implemented the Rp pull-up as a resistor to the VBUS line.

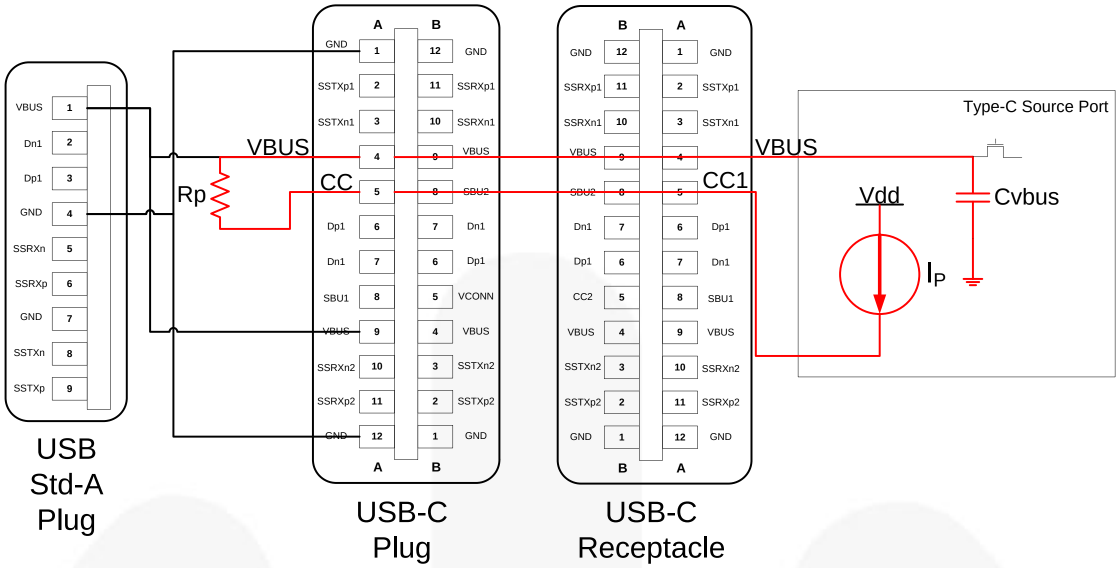

Figure 1. Type-C to Standard-A Dangling Cable Connection

A Type-C port controller source port, such as the FUSB301/A or FUSB302, detects an insertion by pulling up the CC pin and monitoring that the CC pin is pulled low by a Type-C sink port, which contains a pull-down on the CC pin. When the Type-C source port (SRC) detects that it is attached, it then enables VBUS to complete the connection.

Type-C source ports will have a pull-up on the CC pin and some capacitance on the VBUS pin as part of the Type-C insertion detection and control. When the Type-C source port is connected to the dangling Type-C to standard-A cable it creates a circuit that is shown in Figure 2.

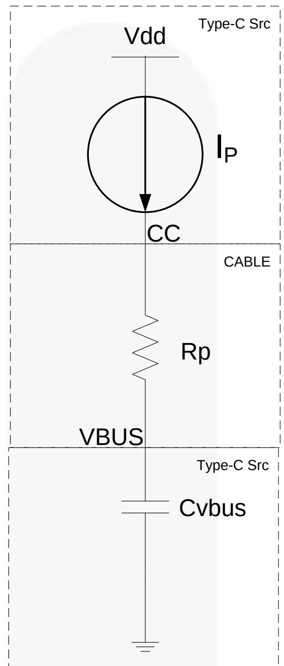

Figure 2. Type-C to Standard-A Dangling Cable Circuit

The Type-C SRC port state diagrams (Section 4.5.2.1, Figure 4-12, page 121) show a transition from Unattached.SRC to AttachWait.SRC when a Rd termination is detected. In the AttachWait.SRC state, the SRC port then debounces the CC pin for $t_{CCDebounce}$ and enters the Attached.SRC state where it asserts VBUS. The threshold used by the SRC to determine if a SNK port is attached is dependent on the host current used but for this paper we will assume that Default USB is used. For Default USB, the detection threshold to determine the CC pin is attached is 1.6 V. Figure 3 shows what the CC pin voltage will look like when a dangling C to A cable or the specific type of Type-C wall charger is attached to a SRC port. The initial attach voltage, V_{CC_SOURCE} is a function of the resistance in the cable and the pull-up current of the SRC port. V_{CC_SOURCE} would be used by the Type-C SRC port to transition from Unattached.SRC to AttachWait.SRC if it is below 1.6 V. The final voltage is dependent on the capacitance on the VBUS pin and the debounce time used by the Type-C SRC port to transition from the AttachWait.SRC state to the Attached.SRC state. If V_{BC_LEVEL} remains below the open voltage threshold of 1.6 V when the $t_{CCDebounce}$ timer expires then the Type-C SRC port would successfully transition to the Attached.SRC state and assert VBUS.

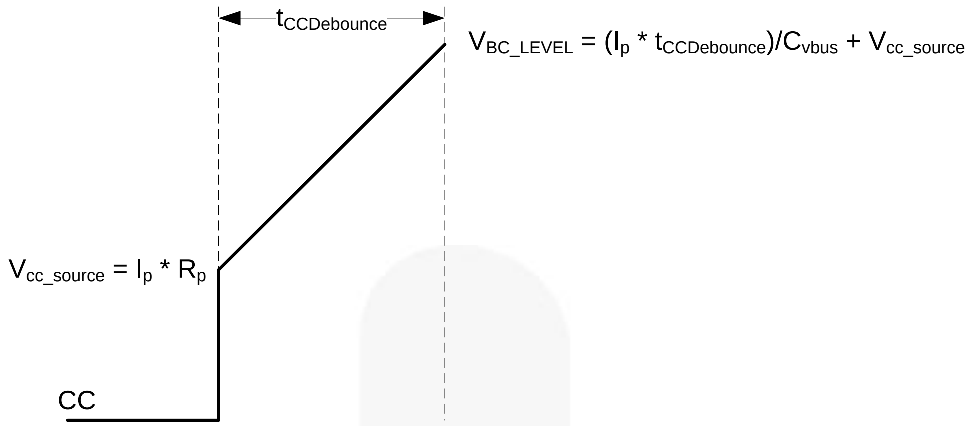

Figure 3. Type-C Source Attach Detection

Assuming the port has Default USB pull-up current and the maximum 10 µF VBUS capacitance, Table 1 shows what V_{CC_SOURCE} and V_{BC_LEVEL} would be across various Type-C resistance values and $t_{CCDebounce}$ timing. Note some of the values for Rp assume incorrectly designed adapter cables which use Rd terminations instead of Rp terminations or illegal Rp terminations that could be present in the Type-C marketplace. Table 1 shows that for certain values of Rp and $t_{CCDebounce}$, that a Type-C SRC port would incorrectly attach as a source. When the SRC port attaches, it asserts VBUS which forces the CC pin above the V_{BC_LEVEL} attach threshold which then causes the SRC port to detach and disable VBUS and enable the pull-up again and the cycle continues shown in Figure 4.

Table 1. Type-C Source Attach Detection

Parameters					V_{CC_SOURCE}	V_{BC_LEVEL}		Notes
I_P	R_P	Cvbus	$t_{CCDebounce}$					
			Min.	Max.	Min.	Min.	Max.	
80 µA	1 K	10 µF	100 ms	200 ms	0.080	0.880	1.680	Incorrect Ra in cable
	5.1 K				0.408	1.208	2.008	Incorrect Rd in cable
	10 K				0.800	1.600	2.400	Illegal Rp in cable
	22 K				1.760	2.560	3.360	Illegal Rp in cable
	56 K				4.480	5.280	6.080	Legal Rp in cable

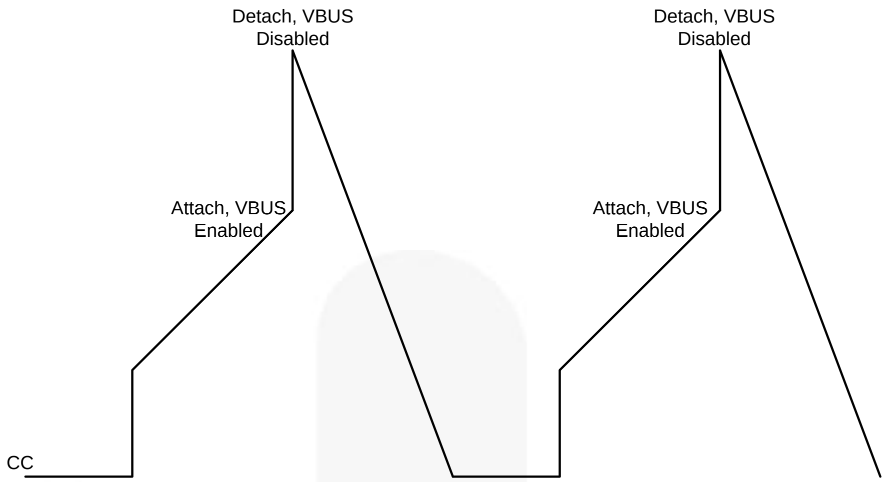

Figure 4. Type-C Source Attach/Detach Oscillations

Solutions

The Type-C source port could decide to implement the $t_{CCDebounce}$ timer so that it is the maximum allowed time in the Type-C specification. This would cover most cases but could be marginal given tolerances of the various resistor and capacitor values defined in the USB Type-C specification. In the Type-C wall charger cases, if the charger is using a captive cable then the capacitance can be much larger which requires addition time for the V_{BC_LEVEL} to exceed the V_{BC_LEVEL} attach threshold.

Another work-around is for the Type-C source port to advertise a higher current capability during the attach detection phase and then switch the advertisement to the capabilities of the port when the attach occurs. This will provide a higher V_{CC_SOURCE} and prevent oscillations when a dangling Type-C to A adapter cable or Type-C wall charger is attached. This is summarized in Table 2. The attach threshold is dependent on the advertised Type-C current that the source port is advertising but for the Default and 1.5 A options the thresholds are the same with a higher threshold for the 3 A advertisement. It is recommended to use the 1.5 A advertisement which will prevent an attach occurring for all the possible cases of R_P in the adapter cable. For Type-C source ports that only want to advertise Default current, these ports can start with the 1.5 A advertisement and then immediately switch to the Default advertisement when entering the attached state.

Fairchild Specific Implementations

For the FUSB301/A, the advertised host current is controlled by the HOST_CUR1 and HOST_CUR0 bits in the Control register. Setting these bits to HOST_CUR1=0b1 and HOST_CUR0=0b0 programs the FUSB301/A to advertise the 1.5 A current and setting these bits to HOST_CUR1=0b0 and HOST_CUR0=0b1 programs the FUSB301/A back to Default current.

For the FUSB302, the current is controlled by the HOST_CUR1 and HOST_CUR0 bits in the Control0 register. The same settings can be used as the FUSB301/A.

Table 2. Type-C Source Detection with 1.5 A Settings

Parameters					V_{CC_SOURCE}	V_{BC_LEVEL}		Notes
I_P	R_P	Cvbus	$t_{CCDebounce}$					
			Min.	Max.	Min.	Min.	Max.	
180 µA	1 K	10 µF	100 ms	200 ms	0.180	1.980	3.780	Incorrect Ra in cable
	5.1 K				0.918	1.718	4.518	Incorrect Rd in cable
	10 K				1.800	3.600	5.400	Illegal Rp in cable
	22 K				3.960	5.760	7.560	Illegal Rp in cable
	56 K				10.080	11.880	13.680	Legal Rp in cable

References

[1] *Universal Serial Bus Type-C Cable and Connector Specification, Revision 1.1*

Related Information

FUSB301- Product Information

FUSB301A-Product Information

FUSB302 - Product Information

PUBLICATION ORDERING INFORMATION

LITERATURE FULFILLMENT:
Literature Distribution Center for ON Semiconductor
19521 E. 32nd Pkwy, Aurora, Colorado 80011 USA
Phone: 303−675−2175 or 800−344−3860 Toll Free USA/Canada
Fax: 303−675−2176 or 800−344−3867 Toll Free USA/Canada
Email: orderlit@onsemi.com

N. American Technical Support: 800−282−9855 Toll Free USA/Canada
Europe, Middle East and Africa Technical Support:
Phone: 421 33 790 2910
Japan Customer Focus Center
Phone: 81−3−5817−1050

ON Semiconductor Website: **www.onsemi.com**

Order Literature: http://www.onsemi.com/orderlit

For additional information, please contact your local Sales Representative